Feynman Disk Problem

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When faced with problems in one or two dimensions looking towards forces, momentum, and energy is usually the best method of attack. Matters suddenly get hairier when we deal with rotational kinematics. While our methods are still valid, we must take extra care to view the problem in different frames of rotation. This is probably the least intuitive and most rigorous area of classical mechanics. If wobbling coins and merry-go-rounds have not inspired you enough to run for a physics textbook, maybe the following problem will:

Problem: Derive the ratio of wobble frequency to the rotational velocity of a disk which is given an initial velocity and thrown upwards. Use the coordinates and Euler angles provided in the figure. Notice that the vectors in red are in respect to the frame of the disk as it is given some initial angular velocity and spinning in the air. The black vectors are in respect to the disk initially (traced out by the dotted line).

Remark. *This problem is quite literally a "spin off" of Richard Feynman's problem. The answer is well known and quite elegant (if you don't know search it up) but this by no means implies the derivation is easy. In fact, this is a crazy problem.*